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OPERATING INSTRUCTION MANUAL FOR TYPE 320-AB PHASE METER

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SECTION I

GENERAL DESCRIPTION

1.1 Purpose of Equipment

The purpose of the Type 320-AB Phase Meter is to measure the phase angle in degrees between two sinusoidal or non-sinusoidal voltages in the frequency range of 20 cycles to 100 kilocycles.

The instrument is designed for either relay-rack or cabinet mounting. A hand-rubbed mahogany cabinet is available as optional equipment.

The Phase Meter measures phase angle by comparing corresponding zero-axis crossings of the periodic signals applied.

1.2 Purpose of Instruction Manual

The purpose of this Instruction Manual is to familiarize the operator with the operating procedure, theory of operation, maintenance, and any special procedures or techniques which might aid in the use of the instrument.

This manual applies to all Type 320-AB units beginning with serial number 441. It also applies to the earlier Type 320-A with the exception of the power supply section.

1.3 Equipment Supplied

Type 320-AB relay-rack mounting
Panel: 19" x 7"
Depth behind panel: 8-5/8"

or

Type 320-AB cabinet mounted
8-3/8" high x 21-1/2" wide x 10-3/8" deep.

Weight Including Cabinet: 25-3/4 lbs.

A 6 foot power cord

Two spare fuses

1.4 Specifications

1.4.1 Phase angle range: 0 to 360°.

1.4.2 Frequency range: 20 cycles to 100 kilocycles. (Sufficient meter damping is provided to permit satisfactory operation at frequencies as low as 2 to 5 cps).

1.4.3 Amplitude range: 1 to 170 volts peak.

1.4.4 Accuracy: With the 180° phase shifting switches in corresponding positions, the accuracy is 1% of full scale + 3°. With the 180° phase shifting switches in opposite positions, this accuracy may be relied upon up to 20 kilocycles. The error will increase slowly until, at 40 kilocycles, the error may be 3% of full scale or 6°, whichever is the larger.

1.4.5 Wave form: Phase angle as measured by the Type 320-AB Phase Meter is defined as the phase angle difference between corresponding zero-axis crossings of the periodic signals being compared. The average zero-axes correspond to the average values of the a.c. components of the applied periodic voltages. A 180° reversal of either signal can be effected by the 180° phase reversing switches so that the phase difference then measured is that between opposite zero-axis crossings (positive to negative and negative to positive) of the two signals. This phase difference is, therefore, dependent upon wave form symmetry. (This is not the case, however, when the 180° phase reversing switches are in the same corresponding positions.)

1.4.6 Input impedance: The input impedance for each channel is 10 megohms shunted by approximately 13 mmf. The effective impedance magnitude of this combination at 10 kc is slightly greater than 1 megohm.

1.4.7 Range: Phase angle reading are indicated directly on a large panel-mounted meter having four full-scale ranges equal to 360°, 180°, 90° and 36°, and are subdivided as follows:

Range	Degrees per Division
360°	2.5°
180°	2°
90°	1°
36°	.25°

The 180° phase reversing switches are provided for each channel so that the 0° and 180° points may be shifted as desired for operational convenience and so that the expanded 90° scale may be moved to any one of the four quadrants, thus permitting the accurate measurement of small phase angle changes.

1.4.8 Meter Damping: The meter is provided with mechanical damping so that at mid-scale, and at a frequency of 2 cps, the magnitude of oscillation will not exceed +6% of full scale. Even with the large amount of mechanical damping necessary to reduce the pointer oscillation at such low frequencies, rapid meter action with almost critical damping has been retained.

1.4.9 Recorder: Terminals for the connection of a recorder are provided on the terminal plate at the back of the instrument. The current through the recorder circuit is equal to approximately 10 milliamperes for 360°. The impedance inserted in the recorder circuit should not exceed 500 ohms.

1.4.10 Terminals: Jack-top binding posts with standard 3/4" spacing are provided on the panel, and a terminal strip on the back of the chassis is furnished for connection of a recorder and the voltages being measured. This terminal strip makes it possible to have permanent connections at the rear of the instrument when the instrument is relay-rack mounted.

1.4.11 Power Supply: 105-125 volts, 50-60 cycles a.c. Models for 210-250 volts, 50-60 cycles, are available and will be furnished when specified. Total power consumption is approximately 100 watts. An electronic stabilized power supply insures stability of meter indication under varying line voltage conditions.

1.4.12 Tubes:

5	6J6 tubes	1	OA2 tube	1	6080 tube
3	6SN7 tubes	1	5Z4 tube	1	6AU6 tube

1.5 Identification of Controls

1.5.1 CHANNEL A and CHANNEL B: At the extreme left of the panel, two sets of binding posts with standard 3/4 inch spacing are provided for inputs to Channels A and B. Directly behind these binding posts, on the chassis, are two sets of binding posts so that permanent connections may be made when relay-rack mounting is employed.

1.5.2 0° - 180° Switches: Each signal channel contains a 180° phase reversal switch. In normal operation these switches are kept in the 0° position. Their purpose is to make possible "expanded scale" operation between the frequency limits of 20 cycles and 20 kc.

1.5.3 FULL SCALE ADJ.: Setting full scale by means of this control is the only calibration necessary before making phase angle measurements.

1.5.4 METER Switch: In addition to altering the metering circuit to permit full-scale sensitivities of 360°, 180°, 90° and 36°, the METER switch provides a check position which has two functions. One is to calibrate the instrument, and the other is to inactivate the measuring circuits for stand-by operation.

1.5.5 NORMAL-REVERSE Switch: Under ordinary operating conditions, with the NORMAL-REVERSE switch in the NORMAL position, the meter reads the angle by which

A leads B; in the REVERSE position the meter reads the angle by which B leads A. This feature in conjunction with the 0°-180° switches, makes it possible to move the 90° range to any of the four quadrants. Thus, "expanded scale" operation, with greatly increased accuracy in measuring phase angle changes, is available, provided the frequency of the applied signal lies between 20 cycles and 20 kc.

1.5.6 ON-OFF Switch: A two position toggle switch for turning the instrument on and off.

SECTION II

OPERATING INSTRUCTIONS

2.1 General Operating Procedure

2.1.1 - When received, the instrument is ready for immediate use. Make sure all accessories have been removed from the packing box. If the instrument has been damaged in shipment, see Section 5.3, Material Damaged in Shipment.

2.1.2 - Connect the instrument to the 115 V AC line, throw power switch to ON and allow at least five minutes for warmup. The meter may give erratic indications with no signal applied to the input terminals or with the input terminals grounded.

2.1.3 - Apply signals whose phase relationship is desired. Check that the amplitudes of signals at the channel inputs is between 1 and 170 volts peak.

2.1.4 - With 0° - 180° switches in any position, NORMAL-REVERSE switch in NORMAL position, and METER switch in CHECK position, set meter to full-scale by means of the FULL-SCALE ADJ. control.

2.1.5 - With 0° - 180° switches both in 0° position, NORMAL-REVERSE switch in NORMAL position, METER switch in any of its four operating positions (360°, 180°, 90° or 36°), the meter reads directly the phase angle by which A leads B.

2.2 Special Operating Procedure

2.2.1 - By the use of the 0° - 180° switches, it is possible to shift the phase of either or both channels by 180°. This makes possible "expanded scale" operation for measurement of small angle changes in any of the four quadrants.

2.2.2 - When the NORMAL-REVERSE switch is in the NORMAL position, the meter reads the angle by which A leads B. By throwing the switch to REVERSE, the meter reads the angle by which B leads A.

2.2.3 - As an example of 2.2.1 and 2.2.2, assume, with the channel switches at 0 and the NORMAL-REVERSE switch at NORMAL, a reading of 200° is obtained and it is desired to read variations of a few degrees. By throwing one of the channel switches to 180° the meter will read 20° and it is now possible to set the METER switch to 36° and observe the small variations over an expanded scale.

As another example, if the meter read 170°, it is possible to throw the NORMAL-REVERSE switch to REVERSE, the meter would read 190°, throw one of the channel switches to 180° and the meter would read 10°. Then, by setting the METER switch to 36°, small variations around 170° could be observed on an expanded scale.

2.2.4 - In order to observe a phase shift passing through or very close to zero degrees, set the METER switch to 360° and the 0° - 180° switches in opposite positions. Tie both channel inputs together and apply one of the test signals noting the meter reading, angle 1 (it will be very nearly 180°). Now apply the two signals to be compared to the two chan-

nels in the normal manner and note the reading, angle 2. The true angle may be calculated by subtracting angle 1 from angle 2.

2.2.5 - Since this instrument measures phase by comparing zero axis crossings, it has the ability of detecting any zero axis instability in the applied signals and showing it as an erratic meter indication. If the signal source has this undesirable effect, it may be minimized or eliminated by operating the signal source from a line voltage regulating device.

2.2.6 - The relative accuracy of the instrument is considerably better than the absolute accuracy. For instance, an indicated change of from 190° to 220° may be relied upon to better than 2% of the 30° change or .6°, whereas the absolute accuracy would be 1% of full scale plus 3° or 6.6°.

2.2.7 - When using the Type 320-AB in conjunction with a recorder, it must be kept in mind that the impedance presented to the "RECORDER" terminals of the Type 320-AB must be 500 ohms or less. If the input impedance of the recorder is more than 500 ohms, shunt the "RECORDER" terminals of the Type 320-AB with a 500 ohm resistor. The voltage appearing across a 500 ohm impedance will be about 5 volts for a reading of 360° and will vary linearily to 0 volts at 0°

Both "RECORDER" terminals are approximately 125 volts above chassis ground.

2.3 General Operating Techniques

2.3.1 - When measuring angles near zero degrees, the meter may give an erratic reading. For measurement of angles near zero degrees see Section 2.2.4.

2.3.2 - The meter will indicate the phase angle between the voltages appearing across the input terminals. If long leads are used to apply the input signals, there may be a phase shift due to the lead capacity which will give an erroneous reading. Always keep the leads as short and as far away from surrounding equipment as possible. Shielded leads should not be used without realizing that their shunt capacity may cause phase shift.

2.3.3 - With no signal applied to the input terminals, or with the input terminals shorted to ground, the meter may give an erratic indication. This is due to the regenerative action of V3 or V7 and is normal.

2.3.4 - The phase angle, as indicated by this instrument, is the result of comparing zero axis crossings of the two applied signals. The average zero-axes correspond to the average values of the a.c. component of the applied signals. A phase reversal of 180° can be effected for either signal by reversing one of the 0° - 180° channel switches. Under this condition, the phase difference between opposite zero-axis crossings (positive to negative and negative to positive) of the applied signals is indicated and the resulting angle will depend upon the wave form symmetry. If the applied signals have unsymmetrical wave forms, the phase reversal switches should be operated in corresponding positions or apparently erroneous results will obtain.

SECTION III

THEORY OF OPERATION

3.1 Detailed Description

3.1.1 Clipper Amplifiers: The first three tubes in each channel are clipper amplifiers whose primary function is the production of square waves with short rise times. The circuitry used is that of the conventional cathode clipper amplifier; V3 and V7 also employ positive feedback.

3.1.2 Phase Inverters: The first triode sections of V1 and V5 are cathode followers which present an input impedance of approximately 10 megohms shunted by 13 uuf (approximately 1 megohm at 10 kilocycles).

Clipper amplifiers V2 and V6 also function as phase inverters for the purpose of measuring small angle changes in any of the four quadrants. The 1N34 germanium crystals, X1 and X2, function as biased diode clippers to aid in the production of square waves.

3.1.3 Differentiators: Each half of the 6J6, V4, is a differentiator whose function is to produce sharp negative pulses used to trigger the flip-flop tube. The negative pulses are formed as the grid goes positive in the following manner. As the voltage at the grid goes negative, the tube cuts off and allows C10 or C20 to charge to the supply voltage level through R13 plus R15 or R28 plus R30.

When the grid voltage goes positive, the tube saturates and provides a low resistance path to ground through which C10 or C20 rapidly discharges, producing a large, sharp negative pulse across R15 or R30. This pulse is consistent with the rise time of the square wave at the grid.

3.1.4 Flip-Flop Circuit: The 6SN7, V8, functions as the flip-flop tube whose action is to assimilate the information, in the form of pulse trains, from the two channels and activate the meter according to their phase relationship.

Only one section of the flip-flop tube conducts at a time, the other side being cut off. The action is such that if a negative pulse is applied to the conducting side, it will be cut off and cause the other side to conduct. This action is almost immediately reversible and will, in the Type 320-AB, operate up to slightly over 100 kilocycles.

If the meter is in series with the channel B side of the flip-flop, as is the case when the NORMAL-REVERSE switch is in the NORMAL position, the meter will read 360° if channel B is conducting. If the channel B side is now turned off and on at intervals governed by the arrival of pulses from the two channels, the meter will read an average of these square pulses of cathode current. The pulse width will be determined by the time lapse between turning channel B side on, with a pulse from channel A, and turning channel B off, with a pulse from channel B. This is a direct measure of the phase difference of the applied signals and indicates the angle by which channel A leads channel B.

By throwing the NORMAL-REVERSE switch to REVERSE, the meter is switched to the channel A side of the flip-flop and will read the angle by which channel B leads channel A.

3.1.5 Recorder: The two terminals, marked RECORDER, on the top of the chassis are provided for employing an external recorder to monitor the phase readings. The recorder must have an impedance of 500 ohms or less, or the operation of the flip-flop circuit will be impaired. If the impedance of the recorder is more than 500 ohms a resistor may be shunted across the terminals to meet the 500 ohm requirement.

3.1.6 Power Supply: An electronic stabilized power supply is utilized to assure stable operation under poor line voltage conditions. Only the severest transient will affect the instrument.

SECTION IV

MAINTENANCE

4.1 Routine Maintenance

Whenever malfunction is suspected, or as a guard against malfunction (monthly or other routine inspection), the following test will determine whether recalibration or other repairs are necessary. If it is felt that regular inspection of tubes is necessary, use caution as to return them to their original sockets - DO NOT INTERCHANGE TUBES!!

Apparatus: - 1000 cps low distortion oscillator capable of 10 volts peak output and having a stable zero axis characteristic. Two 1000, 5000, or 10,000 ohm Technology Instrument RVL3 potentiometers or equivalent. ac Voltmeter.

Connect apparatus as shown in Section 5.2.3 and adjust output of oscillator to 10 volts peak (then the voltage applied to either channel may be read directly from the potentiometers).

When using the 360^{o} scale, the Phase Meter should indicate 180^{o} for all of these preliminary tests.

A. 1. Apply 5 volts to Channel A and 10 volts to Channel B.
   2. Throw 0^{o} - 180^{o} switches to opposite positions.
   3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.

B. 1. Apply 5 volts to Channel B and 10 volts to Channel A.
   2. Throw 0^{o} - 180^{o} switches to opposite positions.
   3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.

C. 1. Apply 1 volt to Channel A and 10 volts to Channel B.
   2. Throw 0^{o} - 180^{o} switches to opposite positions.
   3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.

D. 1. Apply 1 volt to Channel B and 10 volts to Channel A.
   2. Throw 0^{o} - 180^{o} switches to opposite positions.
   3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.

E. 1. Apply 1 volt to Channel A and 10 volts to Channel B.
   2. Reverse NORMAL-REVERSE switch and note change in meter reading.

F. 1. Apply 1 volt to Channel B and 10 volts to Channel A.
   2. Reverse NORMAL-REVERSE switch and note change in meter reading.

If any of the above tests show a change in meter reading of more than one division, follow the procedure in Section 4.3, Recalibration.

4.2 Special Maintenance

If the instrument appears to be operating improperly, one or more of the following sections may help in securing proper operation.

4.2.1 Unstable Meter Indication: Check for zero axis stability of the applied signals.

The circuitry employed in the Phase Meter is such that a shift in the zero axis of the observed signals (because of power supply or other instability) will become apparent by a momentary variation in phase angle meter indication. The Phase Meter utilizes the time difference between zero axis crossings as a measure of phase angle so that if the zero axis shifts the time difference between zero axis crossings may also shift and the result is a jittery meter indication.

A simple check for the above condition may be made by connecting a dc voltmeter across either input of the Phase Meter and

if the instability of the indicating meter coincides with the fluctuations of the dc meter, the above condition does exist.

Check that the input voltage and frequency are within the specified limits. An input voltage in excess of 170 volts peak may result in damage to the instrument. Signal amplitudes of less than one volt peak will cause the flip-flop to become unstable due to erratic triggering pulses. Always measure the signal amplitude directly at the channel input terminals.

Check that the power line does not have exceptionally large transients and is at least 105 volts.

Check that the power supply is operating properly, see Section 4.3.3.

If the phase shift of the device being measured is a function of frequency, check that the signal source in use is frequency stable.

4.2.2 Erroneous Meter Indication: See Section 4.1, Routine Maintenance.

When making measurements in high impedance circuits, the length and capacity of the connecting cables must be considered. A wide variation in phase angle may result even at low frequencies because of the addition of a few micromicrofarads of capacity. Do not make the mistake of applying the usual voltage measurement techniques to phase measurement.

If the instrument fails to operate at low frequencies, try a new 6SN7 for V3 or V7. If one of these tubes is replaced, recalibration will be necessary.

If the meter readings do not agree between ranges, measure the meter multiplying resistors R46 through R49 with a precision bridge.

4.2.3 Meter Reading Drifts: Check power line voltage to be at least 105 volts and to be free of severe transients.

If the phase shift being measured varies with frequency, check that the frequency source is stable.

4.2.4 Meter Reading Amplitude Sensitive: See Section 4.3, Recalibration.

If the emission of any channel tube falls below normal, particularly V1 and V5, the calibration may change as filament voltage changes with line voltage change. This may be eliminated by tube replacement or by operating the instrument from a line voltage regulator.

4.3 Recalibration

4.3.1 Flip-Flop Adjustment: No apparatus necessary.

A. Set METER switch on check, set meter to full scale by FULL SCALE ADJ. control.

B. Set TEST A-NORMAL- TEST B switch to TEST A, NORMAL-REVERSE switch on NORMAL, METER switch on 360^{o}, note meter reading.

C. Set TEST A-NORMAL-TEST B switch to TEST B, NORMAL-REVERSE switch to REVERSE, METER switch on 360^{o}, note meter reading. Meter should read full scale for steps B and C. Adjust R41 until this condition exists. Recheck step A after each adjustment of R41.

4.3.2 Calibration Potentiometer Adjustment: Apparatus: Same as Section 4.1.

Connect and adjust apparatus the same as in Section 4.1.

A. 1. Apply 5 volts to Channel A and 10 volts to Channel B.
   2. Throw 0^{o} - 180^{o} switches to opposite positions.
   3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.
   4. Adjust R63 until there is no shift in reading between A2 and A3.

B. 1. Apply 5 volts to Channel B and 10 volts to Channel A.
2. Throw 0^{o} - 180^{o} switches to opposite positions.
3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.
4. Adjust R80 until there is no shift in reading between B2 and B3.

Repeat A and B until no longer necessary.

C. 1. Apply 1 volt to Channel A and 10 volts to Channel B.
2. Throw 0^{o} - 180^{o} switches to opposite positions.
3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.
4. Adjust R53 until there is no shift in reading between C2 and C3.

D. 1. Apply 1 volt to Channel B and 10 volts to Channel A.
2. Throw 0^{o} - 180^{o} switches to opposite positions.
3. Reverse 0^{o} - 180^{o} switches and note change in meter reading.
4. Adjust R81 until there is no shift in reading between D2 and D3.

Repeat C and D until no longer necessary.

E. 1. Apply 1 volt to Channel A and 10 volts to Channel B.
2. Reverse NORMAL-REVERSE switch and note change in meter reading.
3. Adjust R62 until there is no shift in reading when NORMAL-REVERSE switch is operated.

F. 1. Apply 1 volt to Channel B and 10 volts to Channel A.
2. Reverse NORMAL-REVERSE switch and note change in meter reading.

Adjust R78 until there is no shift in reading when NORMAL-REVERSE switch is operated.

G. Repeat the procedure outlined in 4.1 (Routine Maintenance) to determine if further readjustments (repeat of 4.3.2) of calibrating potentiometers are necessary.

4.3.3 Power Supply Adjustment:

Purpose: To adjust the electronic stabilized power supply for optimum operation.

Apparatus: Oscilloscope
Multitester
Variac

4.3.3.1 Connect the oscilloscope and the dc voltmeter to pin 3 or 6 of V9, 6080. Adjust R91 for a reading of 290 volts. No signals should be applied to the channels.

4.3.3.2 Adjust the oscilloscope for maximum vertical gain and increase the line voltage in quick steps of about 5 volts from 105 to 125 volts. Note that the trace on the oscilloscope jumps up and then down over this range. The point at which the trace reverses direction is the point of optimum regulation. R104 will shift this point over most of the range of 105 to 125 volts and is usually set for 115 volts but may be set for any existing line voltage conditions within its range of adjustment.

4.3.3.3 R91 and R104 interact so that adjustment of either control will necessitate a check of the other.

4.3.3.4 If the oscilloscope has sufficient vertical gain, R104 may be adjusted by observing the hum of the B+ and, with the instrument operating at normal line voltage, adjusting R104 for minimum hum.

SECTION V

SUPPLEMENTARY DATA

5.1 Parts List

Identification of Manufacturers:

Abbreviation	Manufacturer
A-B	Allen Bradley Co.
A H H	Arrow, Hart & Hagerman Electric Co.
Buss	Bussman Mfg. Co.
Clarostat	Clarostat Mfg. Co., Inc.
Cont. Car.	Continental Carbon, Inc.
C-D	Cornell-Dubilier Electric Corp.
G. E.	General Electric Co.
Good-All	Good-All Electric Mfg. Co.
I R C	International Resistance Co.
Kemtron	Kemtron Electric Products Co.
Marion	Marion Electrical Instrument Co.
Mepco	Mepco Inc.
National	National Co.
Oak	Oak Mfg. Co.
R C A	Radio Corporation of America
Sprague	Sprague Electric Co.
T I C	Technology Instrument Corp.

COMPONENT LIST

TYPE 320-AB

Component	Value	Watts	Manufacturer	Type	Remarks
R1	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R2	33K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R3	33K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R4	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R5	10K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R6	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R7	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R8	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R9	6.8K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R10	2.2K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R11	4.7K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R12	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R13	330K	1 W	I R C	B T A	Carbon ± 10%
R14	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R15	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R16	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R17	33K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R18	33K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R19	10 meg.	½ W	A-B	EB1061	Carbon ± 10%

COMPONENT LIST

TYPE 320-AB

Component	Value	Watts	Manufacturer	Type	Remarks
R20	10K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R21	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R22	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R23	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R24	6.8K	1 W	Cont. Car.	X-1	Nobleloy ± 5%
R25	2.2K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R26	4.7K	½ W	Cont. Car	X-1/2	Nobleloy ± 5%
R27	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R28	330K	1 W	I R C	B T A	Carbon ± 10%
R29	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R30	10K	½ W	Cont. Car.	X-1/2	Nobleloy ± 5%
R35	280K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R36	280K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R37	220K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R38	220K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R39	7.5K	1 W	Mepco	WM-3L	Wire wound ± 1%
R40	7.5K	1 W	Mepco	WM-3L	Wire wound ± 1%
R41	1K	2 W	Clarostat	CM4693	Wire wound
R43	10K	2 W	I R C	B T B	Carbon ± 10%
R44	3.5K	2 W	A-B	J	Carbon ± 10%
R45	1410 Ω	1 W	Mepco	WM-3L(S)1	Wire wound ± 1%
R46	464.6Ω	1 W	Mepco	WM-3L(S)1	Wire wound ± 1%
R47	118.3Ω	1 W	Mepco	WM-3L(S)1	Wire wound ± 1%
R48	53.94Ω	1 W	Mepco	WM-3L(S)1	Wire wound ± 1%
R49	50.85Ω	1 W	Mepco	WM-3L(S)1	Wire wound ± 1%
R50	288K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R52	3.3K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R53	200K	2 W	A-B	J	Carbon potentiometer
R54	4.7K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R55	24K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R56	4.7K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R57	2.2K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R58	6.8K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R59	13K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R60	43K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R61	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R62	200K	2 W	A-B	J	Carbon potentiometer ± 10%
R63	200K	2 W	A-B	J	Carbon potentiometer ± 10%
R64	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R66	68K	1 W	I R C	B T A	Carbon ± 10%
R67	22K	½ W	I R C	B T S	Carbon ± 10%
R68	288K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R70	3.3K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%

COMPONENT LIST

TYPE 320-AB

Component	Value	Watts	Manufacturer	Type	Remarks
R71	4.7K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R72	24K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R73	4.7K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R74	2.2K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R75	6.8K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R76	13K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R77	43K	½ W	Cont. Car.	X-1/2	Nobleloy ± 1%
R78	200K	2 W	A-B	J	Carbon potentiometer ± 10%
R79	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R80	200K	2 W	A-B	J	Carbon potentiometer ± 10%
R81	200K	2 W	A-B	J	Carbon potentiometer ± 10%
R82	10 meg.	½ W	A-B	EB1061	Carbon ± 10%
R83	22K	½ W	I R C	B T S	Carbon ± 10%
R84	68K	1 W	I R C	B T A	Carbon ± 10%
R90	47K	1 W	A-B	GB4731	Carbon ± 10%
R91	50K	2 W	A-B	J	Carbon potentiometer ± 10%
R92	47K	1 W	A-B	GB4731	Carbon ± 10%
R93	100Ω	½ W	I R C	B T S	Carbon ± 10%
R94A	150K	½ W	I R C	B T S	Carbon ± 10%
R94B	150K	½ W	I R C	B T S	Carbon ± 10%
R95	220K	½ W	I R C	B T S	Carbon ± 10%
R96	15K	25 W	Clarostat	A12KS	Standee
R97	100Ω	½ W	I R C	B T S	Carbon ± 10%
R98	100Ω	½ W	I R C	B T S	Carbon ± 10%
R99	22Ω	½ W	I R C	BW-1/2	W.W. ± 10%
R100	22Ω	½ W	I R C	BW-1/2	W.W. ± 10%
R101	330K	½ W	I R C	B T S	Carbon ± 10%
R102A	220K	2 W	A-B	HB2241	Carbon ± 10%
R102B	220K	2 W	A-B	HB2241	Carbon ± 10%
R103A & B	500Ω	15 W	Clarostat	A8KS	Standee tapped at 250Ω ± 10%
R104	5K	2 W	A-B	J	Carbon potentiometer ± 10%
R106A	4.7Ω	1 W	I R C	BW-1	W.W. ± 10%
R106B	4.7Ω	1 W	I R C	BW-1	W.W. ± 10%
R107	47Ω	½ W	I R C	BW-1/2	W.W. ± 10%
R108	47Ω	½ W	I R C	BW-1/2	W.W. ± 10%

COMPONENT LIST

TYPE 320-AB

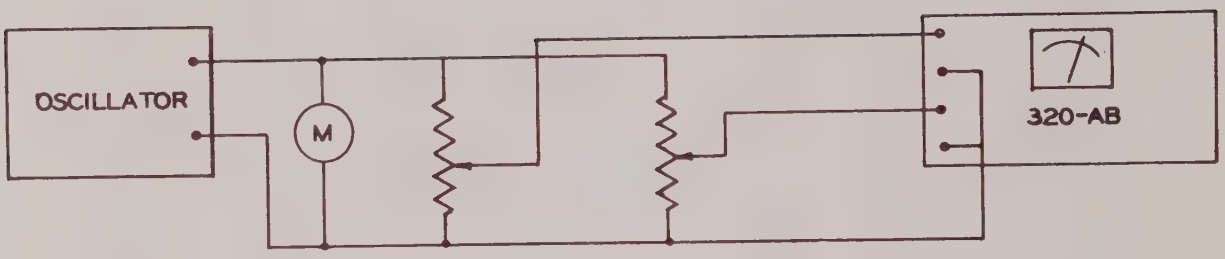
Component	Value	Volts	Manufacturer	Type	Remarks
Condensers:					
C1	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C2	200 uufd	500 V DC	C-D	5W5T2	Mica
C3	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C4	200 uufd	500 V DC	C-D	5W5T2	Mica
C5	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C6	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C7	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C8	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C10	50 uufd	500 V DC	C-D	5W5T2	Mica
C11	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C12	200 uufd	500 V DC	C-D	5W5T2	Mica
C13	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C14	200 uufd	500 V DC	C-D	5W5T2	Mica
C15	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C16	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C17	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C18	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C20	50 uufd	500 V DC	C-D	5W5Q5	Mica
C21	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C22	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C23	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C25	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C26	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C27	.25 ufd	600 V DC	Good-All	COMY-6-254-20	Mylar
C30	82 uufd	500 V DC	C-D	5W5Q82	Mica
C31	82 uufd	500 V DC	C-D	5W5Q82	Mica
C32	39 uufd	500 V DC	C-D	5W5Q39	Mica
C34	500 uufd	500 V DC	C-D	5W5T5	Mica
C40	20 ufd	450 V DC	Sprague	UP2045	Electrolytic
C41	.05 ufd	400 V DC	Sangamo	300415	Paper
C42	50 uufd	500 V DC	C-D	5W5Q5	Mica
C43	50 uufd	500 V DC	C-D	5W5Q5	Mica
C44	39 uufd	500 V DC	C-D	5W5Q39	Mica
C46	20 ufd	475 V DC	Sprague	D14940	Electrolytic-part of 20 uf can.
C47	20 ufd	475 V DC	Sprague	D14940	Electrolytic-part of 20 uf can.
C48	40 ufd	475 V DC	Sprague	D14940	Electrolytic-part of 20 uf can.

COMPONENT LIST

TYPE 320-AB

Component	Value	Volts	Manufacturer	Type	Remarks
Tubes:					
V1			R C A	6J6	
V2			R C A	6J6	
V3			R C A	6SN7GT	
V4			R C A	6J6	
V5			R C A	6J6	
V6			R C A	6J6	
V7			R C A	6SN7GT	
V8			R C A	6SN7GT	
V9			R C A	6080	
V10			R C A	6AU6	
V11			R C A	OA2	
V12			R C A	5Z4	
Chokes:					
L1	2.5 mh		National	R-100S	
L2	2.5 mp		National	R-100S	
Crystals:					
X1			Kemtron	1N34	
X2			Kemtron	1N34	
Meter:					
M1	275 ua		Marion	MRDS-4	
Fuses:					
F1 and F 2	2 amp		Littlefuse	3AG	Slow-blow
Pilot Light:			G E	#44	
Switches:					
S1, S2, S4			AHH	SWT22A	DPDT
S3			Oak	SRW102	3 pos. 2 gang
S6			AHH	SWT21A	DPST
S5			Oak	SRW101	5 pos. 2 gang
Transformer:					
T1			TIC	TRP20	

5.2.3 Circuit for Calibration:



5.3 Material Damaged in Shipment

Address Correspondence to:

Acton Laboratories, Incorporated
Service Department
533 Main Street
Acton, Massachusetts
Telephone Acton 3-7756

If, upon receipt of your instrument, the packing case shows evidence of damage, or if upon unpacking, damage is found which appears to have been caused by shipment, do not unpack or discard any of the packing. Notify immediately the local office of the carrier and request that they inspect the damage. Also notify Acton Laboratories, Incorporated of the type number, serial number, extent and type of damage, our invoice number, carrier's number, date received and any other pertinent information so that we may contact our local carrier office in order to facilitate a speedy settlement of any claim.

5.4 Guarantee

Acton Laboratories, Incorporated guarantees to the original purchaser that all instruments of its manufacture are in accordance with published specifications. Any deviation from these specifications or defects of workmanship or material will be corrected by Acton Laboratories, Incorporated. This guarantee is in effect for one year from date of shipment, with the exception of failures of or attributable to tubes, fuses or batteries. Tubes and batteries are guaranteed under this guarantee for 90 days from date of shipment. This guarantee is valid only if the instrument has been properly used under normal operating conditions. Acton Laboratories, Incorporated will be the sole judge of the validity of all claims.

5.4.1 Filing Claims Under Guarantee:

Address Correspondence to:

Acton Laboratories, Incorporated
Service Department
533 Main Street
Acton, Massachusetts
Telephone Acton 3-7756

Before returning material under the guarantee, contact Acton Laboratories, Incorporated stating type number, serial number and the defect claimed. With this information, our Engineering staff in many cases can review the difficulties and recommend corrective measures, thus eliminating much lost time to our customer as well as many needless and costly returns. If return is necessary, Acton Laboratories, Incorporated will authorize one of two methods. The first method is for returns to be made within 30 days from date of shipment; in this case return Railway Express Collect will be authorized. For returns to be made after the first 30 days of the guarantee, authorization will be given but the return must be made prepaid. Upon completion of repair work done under this guarantee, Acton Laboratories, Incorporated will reship Railway Express Prepaid.

DIMENSIONS IN INCHES
THIRD ANGLE PROJECTION

REVISIONS

R45 - 1410 Ω ± 0.1% TEMP. COEF. ± .00002
R46 - 464.6 Ω ± 0.1% (0.5 Ω)
R47 - 118.3 Ω ± 0.1% (0.1 Ω)
R48 - 53.94 Ω ± 0.1% (0.05 Ω)
R49 - 50.85 Ω ± 0.1% (0.05 Ω)
} TEMP. COEF. ± .0007
C50 - TO BE SELECTED BY T.I.C.

10 V CHANNEL A 1000 ~

10 V CHANNEL B 1000 ~

CONNECT
1-3 & 2-4 FOR 115V
2-3 FOR 230V

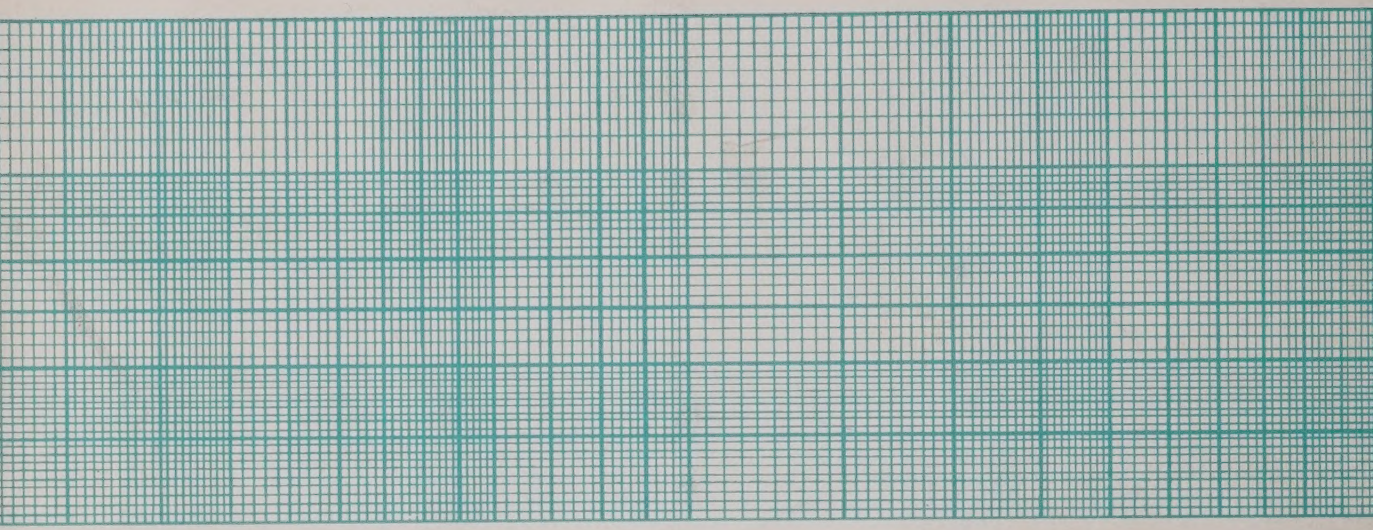
ALL VOLTAGES MEASURED WITH A 20000 Ω/V DC & 5000 Ω/V AC METER UNDER THE FOLLOWING CONDITIONS.

1. METER SWITCH IN CHECK POSITION.
2. BOTH CHANNEL SWITCHES AT 0°
3. INPUT OF TEN VOLTS AT 1000 CPS

ALL CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE NOTED
ALL RESISTANCE VALUES IN OHMS UNLESS OTHEWISE NOTED
K = 1000 M = MEGOHM *SELECTED

STANDARD TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± .010"
DECIMALS ± .005"
ANGLES 1/2°
FINISH TURNING CONCENTRIC TO .003 INDICATOR READING.
ALL PIECES MUST BE CLEAN AND FREE OF BURRS.

SCALE:
PHASE METER 320AB
ACTON LABORATORIES INC.
ACTON, MASS., U.S.A.
DR. H 9-8-53 ENG. APP.
CH. PROD. APP.
DWG. NO. 320AB-4DE/5



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